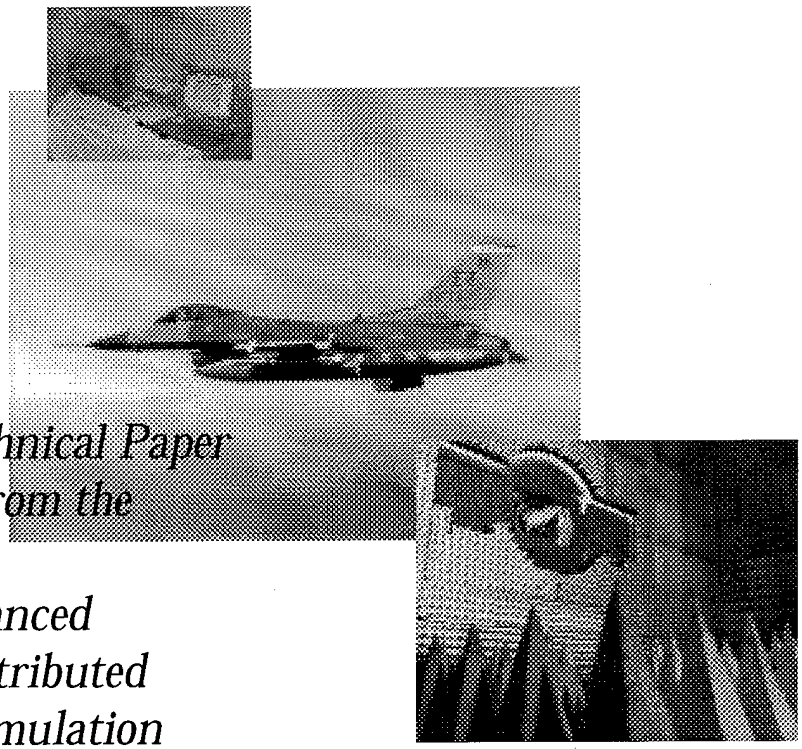
The Benefits of Using Advanced Distributed Simulation for Air-to-Air Missile Test and Evaluation



A Technical Paper from the Joint Advanced Distributed Simulation Joint Test Force

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THE BENEFITS OF USING ADVANCED DISTRIBUTED SIMULATION FOR AIR-TO-AIR MISSILE TEST AND EVALUATION

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Abstract

The Joint Advanced Distributed Simulation (JADS) Joint Test and Evaluation (JT&E) was chartered by the Office of the Secretary of Defense (Acquisition and Technology) in October 1994 to investigate the utility of advanced distributed simulation (ADS) technologies for support of test and evaluation (T&E). The JADS Joint Test Force (JTF) conducted a System Integration Test (SIT) in which ADS was used to support the testing of an integrated missile weapon/launch aircraft system in operationally realistic scenarios. The SIT scenarios simulated a single shooter aircraft launching an air-to-air missile against a single target aircraft. Extensive testing was performed involving two different ADS architectures:

- A linked laboratory configuration in which the shooter and target were represented by manned flight laboratories and the missile by an AIM-9M Sidewinder hardware-in-the-loop (HWIL) laboratory.
- A live shooter/target configuration in which the shooter and target were represented by live F-16 fighters and the missile by an AIM-120 Advanced Medium Range Air-to-Air Missile (AMRAAM) HWIL laboratory.

Testing was completed in October 1997, and evaluation of the results supports the conclusion that each ADS configuration has utility for T&E of the corresponding air-to-air missile involved.

This paper discusses the following:

- Description of the two different architectures utilized in the SIT testing.
- Technical challenges in implementing ADS.
- Lessons learned from implementing ADS.
- Conclusions on the utility of ADS-based testing of air-to-air missiles.
- Benefits of implementing ADS-based testing of air-to-air missiles.

Overview

The JADS JT&E program was chartered by the Office of the Secretary of Defense in October 1994 to investigate the utility of ADS technologies for support of T&E. The JADS JTF is Air Force led, with Army and Navy participation, and is scheduled for completion in 1999. This paper describes the results from the first of three separate JADS tests, the SIT, which was completed in October 1997.

The SIT investigated the ability of ADS to support air-to-air missile testing. The test included two sequential phases, a Linked Simulators Phase (LSP) and a Live Fly Phase (LFP). Both

phases incorporated one-versus-one scenarios based upon profiles flown during live test activities and limited target countermeasures capability.

Linked Simulators Phase (LSP)

The LSP was executed by the JADS JTF and the Naval Air Warfare Center, Weapons Division (NAWCWPNS) between August and November 1996. The one-versus-one scenario utilized in the LSP missions was taken from previous AIM-9M testing.

LSP Architecture

In the LSP, the shooter, target, and missile were all represented by simulation laboratories. ADS techniques were used to link NAWCWPNS manned flight laboratories representing the aircraft to an air-to-air missile hardware-in-the-loop (HWIL) laboratory representing the missile. The LSP test configuration is shown in Figure 1. The F/A-18 Weapon System Support Facility (WSSF) at China Lake, California, and the F-14D Weapon System Integration Center (WSIC) at Point Mugu, California, were the shooter and target, respectively. These laboratories were linked to each other and to an AIM-9M-8/9 HWIL laboratory at the Simulation Laboratory (SIMLAB) at China Lake. Interfacing of the laboratories to the network was by means of network interface units (NIUs). The launch aircraft laboratory "fired" the AIM-9 in the SIMLAB at the simulated target aircraft, and the AIM-9 seeker responded to infrared (IR) sources in the SIMLAB which simulated the IR signatures and relative motions of the target aircraft and the flare countermeasures. Real-time links between the laboratories allowed the players to respond to each other.

The nodes exchanged entity state information with each other by means of distributed interactive simulation (DIS) protocol data units (PDUs). However, the stores management system (SMS) data exchange between the F/A-18 WSSF and the AIM-9 SIMLAB used the tactical military standard 1553 protocol because no suitable DIS protocol exists for these data, because this exchange was only between the WSSF and the SIMLAB, and because use of the tactical protocol was appropriate for integrated weapon system testing.

The test runs were controlled initially by the Battle Management Interoperability Center (BMIC) at Point Mugu and later by the Test Control and Analysis Center (TCAC) in Albuquerque, New Mexico. The control center ensured that all nodes were ready for each run and issued the commands to start and stop the runs. PDUs were processed at the control center to provide JADS test controllers and analysts with real-time stealth node viewing of the simulated engagement.

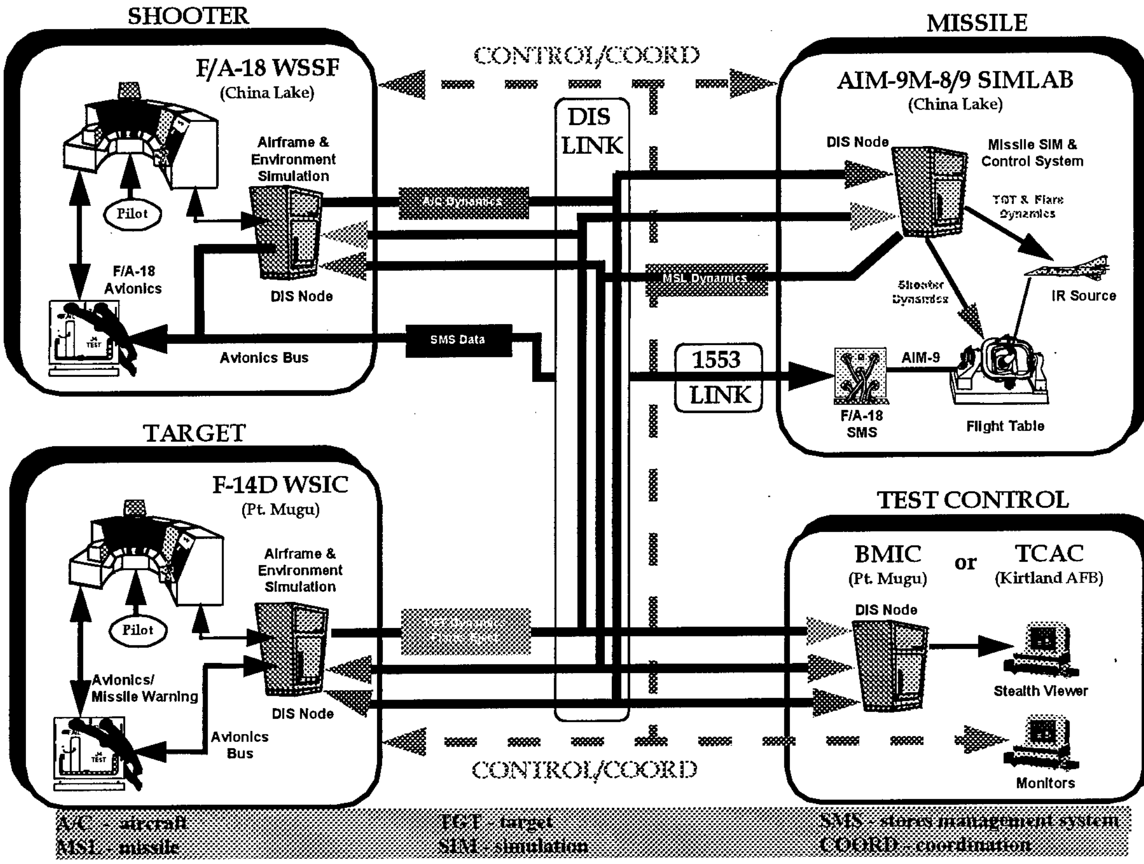

Figure 1. Linked Simulators Phase Test Configuration

LSP Results

LSP results were documented in the final report for that phase (Ref. 1) and other technical papers (Refs. 2 through 4). Key findings were as follows.

- The SIMLAB missile performance was valid for its target representation.
- The manual method for replicating a given profile resulted in very good run-to-run reproducibility of the engagement.
- The average latency of all entity state data was relatively small (<100 milliseconds from simulation to simulation). However, relatively large latency variations were observed which introduced uncertainty in the target position (Ref. 4). The random nature of these variations complicates evaluation of closed-loop interactions between the target and the missile.
- The network provided ample bandwidth.
- There were no significant ADS-induced errors.
- DIS PDUs were adequate for entity state data exchanges.
- The centralized test control procedures worked well.

Live Fly Phase (LFP)

The LFP was executed by the JADS JTF and the 46th Test Wing at Eglin Air Force Base (AFB), Florida, during 1997. The one-versus-one scenarios utilized in the LFP missions were taken from previous AMRAAM testing.

LFP Architecture

In the LFP, the shooter and target were represented by live aircraft and the missile by a simulator. ADS techniques were used to link two live F-16 fighter aircraft flying over the Eglin Gulf Test Range to the AMRAAM AIM-120 Missile Simulation Laboratory (MISILAB) HWIL simulation facility at Eglin AFB. The LFP test configuration is shown in Figure 2.

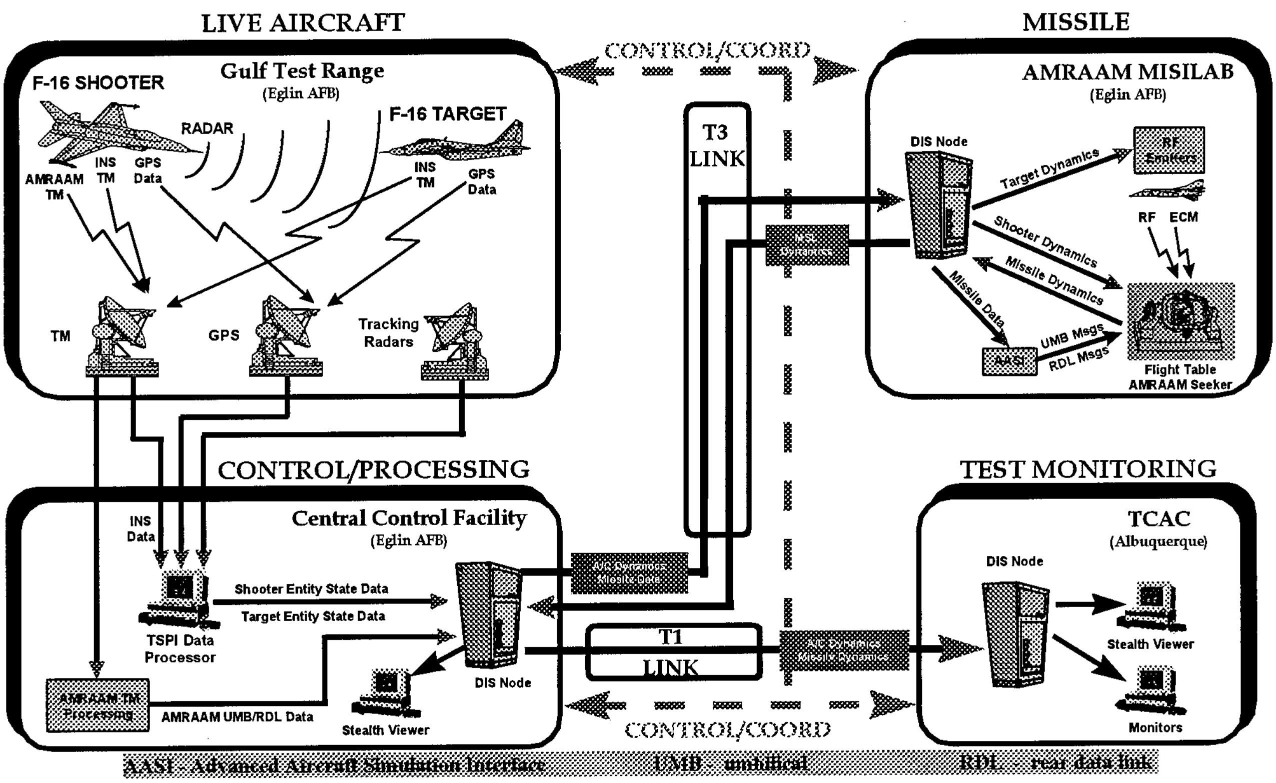

Figure 2. Live Fly Phase Test Configuration

Global positioning system (GPS) and telemetry (TM) data were downlinked from the aircraft and passed to the Central Control Facility (CCF) at Eglin AFB. GPS, inertial navigation system (INS), and tracking radar data for each aircraft were combined by the time-space-position information (TSPI) Data Processor (TDP) in the CCF to produce optimal entity state solutions. The aircraft entity state data were transformed into DIS PDUs and transferred to the AMRAAM HWIL laboratory at the MISILAB over a T3 link (with a bandwidth of about 45 megabits per second). The shooter aircraft "fired" the AMRAAM in the MISILAB at the target and provided data link updates of the target position and velocity to the missile during its flyout. The AMRAAM seeker was mounted on a flight table and responded to radio frequency (RF) sources

in the MISILAB which simulated the seeker return from the target, the relative motions of the target and the missile, and electronic countermeasures (ECM). A T1 link (with a bandwidth of about 1.5 megabits per second) between the CCF and the JADS TCAC allowed JADS personnel to monitor the simulated intercepts.

The actual umbilical and data link messages from the shooter aircraft were used to initialize, launch, and update the missile in the MISILAB during each simulated engagement. The shooter carried a pod which emulated the AMRAAM missile in its prelaunch configuration, and AMRAAM telemetry from the pod was downlinked and processed by the CCF. The telemetry was converted into DIS PDUs and transferred to the MISILAB over the T3 link. The messages were then reconstructed and synchronized to the aircraft TSPI data by the Advanced Aircraft Simulation Interface (AASI) in the MISILAB.

The test runs were controlled from the CCF. The control center ensured that all players were ready for each run and issued the commands to start and stop the passes. PDUs were processed at the TCAC to provide JADS personnel with real-time stealth node viewing of the simulated engagement.

LFP Results

LFP testing was completed in October 1997, and results were documented in the final report for that phase (Ref. 5) and other technical papers (Refs. 6 through 10). Key findings were as follows.

- The MISILAB missile performance was valid for its target presentation, and the target presentation accurately represented the live target. Also, the umbilical and data link messages provided to the MISILAB missile accurately replicated those generated by the shooter.
- The TDP was able to provide the required accuracy of aircraft TSPI. The TDP solutions were estimated to be accurate to within 1-3 meters in position and 1 meter per second in velocity. These values met the MISILAB accuracy requirements.
  - The use of multiple TSPI inputs resulted in robust TDP performance. In particular, periodic GPS dropouts did not significantly degrade the accuracy of the position solution, because the TDP used the accurate INS data to propagate the solution between GPS updates.
- The data required to drive the MISILAB simulation were properly synchronized before being input.
  - Variable processing delays resulted in aircraft entity state data and the umbilical and data link messages arriving at the MISILAB in an unsynchronized fashion.
  - Buffering and time alignment of the data resulted in synchronized inputs.
- Significant latencies resulted from the LFP configuration.
  - Processing of the TSPI data by the TDP and by a post-TDP smoother resulted in latencies of about 2.4 seconds for aircraft entity state data arriving at the MISILAB. Smoothing of the TDP solution was required for proper MISILAB simulation performance.
  - Buffering of the data for synchronization to the MISILAB simulation resulted in an additional 600 milliseconds of latency.
  - Total latency of the missile simulation was about 3 seconds relative to the live aircraft.

- There was good network performance with ample bandwidth, no ADS-induced errors, and no wide area network failures.

Lessons Learned

Lessons learned from SIT testing can be summarized as follows.

- For T&E applications, the technology is not at the "plug-and-play" stage. While practical and cost effective in many cases, implementation is more challenging than many people think. Plan for a lot of rehearsals and "fix" time.
- The architecture build-up must be incremental, beginning with check out of the ADS elements in a stand-alone mode, and evolving, step by step, to the fully integrated configuration.
- Problem solving/fixes frequently require verification in a full-up network configuration.
- Configuration control in a distributed environment is difficult, but essential.
- The effects of latency and other ADS-induced errors can often (not always) be mitigated.
- Data synchronization is as much a challenge as latency management. Synchronization is best based on a "master clock" built into the architecture.
- Instrumentation and data management are more complex in a distributed test.
- Linking may require special purpose interfaces, and their development must be planned for.

Utility Conclusions

An LSP type architecture involving all simulation laboratories has utility for

- Missile weapon/launch aircraft system integration T&E.
- Parametric studies, due to good manual reproducibility of the profile.
- Rehearsal and refinement of live fire engagement scenarios.

An LFP type architecture involving a live shooter and target has utility for

- Missile weapon/launch aircraft system integration T&E, especially evaluation of the targeting messages supplied to the missile by the shooter.
- Rehearsal and refinement of live fire engagement scenarios.
- Tactics development involving closed-loop interactions between the shooter and target.
- Efficient testing utilizing an analyst-in-the-loop for timely feedback during the mission.

ADS Benefits

The benefits of ADS-supported testing are best realized when this technique is added to a total weapon system testing program. ADS-supported tests are not meant to replace any of the current testing techniques, including live fire tests, but rather to supplement current techniques and provide a more comprehensive evaluation of a weapon system. When the appropriate mix of testing techniques is used, the following benefits are realized from the addition of ADS-supported testing:

- Cost savings benefits.
  - A missile testing program which uses ADS-supported tests to supplement live fire tests can be more cost effective than live fire testing alone. In a limited number of cases,

relatively inexpensive ADS-supported tests can replace costly live tests. Generally, live tests are not replaced; instead, the proper use of ADS can result in a higher success rate for the live tests by identifying failures before the fact (cost avoidance) and can aid in the optimal selection of live test scenarios and associated measures. A methodology for determining the cost benefit of mixing ADS missions into a missile testing program is outlined in Appendix B of Reference 11, along with an example of applying the methodology to one phase of AMRAAM testing.

- Improved testing benefits.
  - Testing using a linked laboratory ADS architecture (similar to the LSP architecture) is more reproducible than live fire testing, because scenario conditions are more readily controlled and trials can be replayed for additional missile responses. This allows more trials to be combined for analysis, giving greater confidence in evaluation results.
  - ADS-supported testing allows the evaluation of certain classified techniques in which the ECM device cannot be permitted to radiate its RF emission on an open range. Rather, the ECM emissions can be restricted to the missile HWIL laboratory where they are screened from unauthorized observation and where the effects of the ECM on missile performance can be immediately observed by analysts.
  - ADS allows the force density of the scenario to be increased. The number of friendly and threat systems can be increased by representing them with either manned laboratories (if realistic man-in-the-loop control of the systems is needed) or digital models (if scripted behavior is acceptable). The inability to evaluate system performance in combat-representative environments is a common limitation in operational testing and an area in which ADS can improve the operational test environment (Ref. 12).
  - ADS-supported tests exhibit more realism than either analytical simulation models (because actual hardware is used) or stand-alone HWIL laboratories (because realistic shooter and target inputs are provided).
- More efficient testing benefits.
  - Testing using a live shooter-target ADS architecture (similar to the LFP architecture) is more efficient than live fire testing because the analysts get immediate feedback on each pass of a multiple pass mission. This allows adjustments to be made to the remaining test matrix, if necessary, while the live shooter and target platforms are still on range. This "analyst-in-the-loop" feature of ADS testing would be especially useful in efficiently progressing through an ECM testing matrix which involves varying a number of ECM-related parameters.
  - Live fire tests can be realistically rehearsed using ADS. This would ensure the proper setup of the scenario and reduce wasted live fire attempts in which the proper scenario conditions are not achieved. This use of ADS would also reduce the risk of a live fire testing program by identifying scenarios which cannot be correctly executed or which cannot achieve the stated objectives (Ref. 12).

Summary

The SIT investigated the application of two different ADS architectures to air-to-air missile testing. Both architectures produced valid T&E-quality missile performance data. The SIT results support the conclusion that ADS-supported missile testing has utility in a number of areas. Further, there are benefits to adding ADS-supported tests to a total weapon system testing program, including possible cost savings.

ADS has great potential as a T&E support tool; it is a valuable addition to the tester's tool kit. ADS will not obviate, but in some cases may reduce, the need for live testing.

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NOTE: References 1 through 11 are available at the download area of the JADS web site: http://www.jads.abq.com.

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